

Electrocardiogram Experiment

using latin square design

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24 May, 2021

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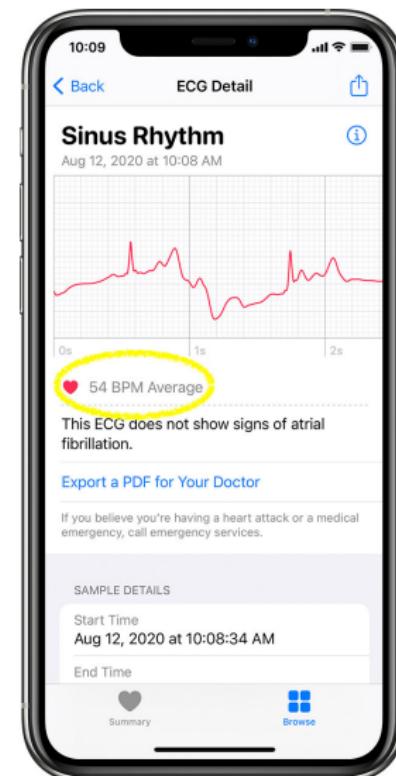
Section 1

Introduction

Electrocardiogram Experiment

Goal

- Does caffeine affect ECG or *heart rate*?
- Caffeine: *coffee*
- Output: Average heart rate (BPM)



Latin Square Design

Table 1: Reduced Latin Square

Row	Column			
	1	2	3	4
1	A	B	C	D
2	B	C	D	A
3	C	D	A	B
4	D	A	B	A

- Each treatment once in each row and column
- We allocate 4 treatment levels randomly

Section 2

Design and the Data

Blocking Factors

Caffeine intake depends on the following two factors (한동하, 2018).

Row: Coffee-to-water ratio

- ① 1:0 (Espresso, 40 ml)
- ② 1:2.5 (Water 100 ml)
- ③ 1:5 (Water 200 ml)
- ④ 1:7.5 (Water 300 ml)

Column: Drinking speed

- ① ≤ 5 sec
- ② 5-15 sec
- ③ 15-30 sec
- ④ $30 <$ sec



Figure 1: Coffee (40 ml)

Factor

Intake of caffeine (himynameisabcde, 2020) from Starbucks by Nespresso

- ① House blend: 74.5 mg
- ② Sumatra: 54.5 mg
- ③ Decaf espresso roast: 3 mg
- ④ Just water: 0 mg

Output

Value: Average heart rate

- in BPM
- Notations from the course (Lee, 2021)
- Since there exists variation, we consider difference of BPM after and before:

$$y_{rc}^{post} - y_{rc}^{pre}$$

Measure

- Apple Watch Series 4
- ECG app
- Algorithm version: 1



Randomized Assignment

- ① Randomly allocate (1, 2, 3, 4) to previous (A, B, C, D)
- ② Assign to above Table 1

```
set.seed(1)
sample(LETTERS[1:4])
#> [1] "A" "C" "D" "B"
```

- Ⓐ House blend (74.5 mg)
- Ⓑ Water (0 mg)
- Ⓒ Sumatra (54.5 mg)
- Ⓓ Decaf espresso roast (3 mg)

Latin Square

Table 2: Design of the Experiment

Water	Drinking Speed			
	<=5	5-15	15-30	30<
0 ml	H(74.5)	W(0)	S(54.5)	D(3)
100 ml	W(0)	S(54.5)	D(3)	H(74.5)
200 ml	S(54.5)	D(3)	H(74.5)	W(0)
300 ml	D(3)	H(74.5)	W(0)	H(74.5)

¹ 'Water' is the coffee-to-water ratio (divide with 40 ml)

² Numbers in the brackets indicate caffeine (in mg)

- Use *reduced latin square*
- Randomization test afterward

Controlling the Other Variables

Coffee

- Drink coffee every morning (between 8:30 a.m. and 9:00 a.m.)
- after eating a piece of bread
- Nespresso machine: Pixie C61 in my home

Measure

- Sitting at the table
- Rest my arms on the table
- Use the same strip
 - Nike sport band
 - of same fit (8-th)
- and other instructions in
<https://support.apple.com/en-us/HT208955>

Experiment



Figure 2: Taking Coffee



Figure 3: Measuring ECG

Section 3

Analysis

Dataset

Table 3: Experiment Data

water	Drinking Speed			
	<=5	5-15	15-30	30<
0 ml	HB, 9	W, 1	S, 7	D, 3
100 ml	W, 2	S, 6	D, 3	HB, 14
200 ml	S, 4	D, 3	HB, 1	W, 0
300 ml	D, 2	HB, 4	W, 2	S, 4

¹ Caffeine: HB > S > D > W

² Numbers indicate the difference after and before taking coffee

Observed Outcomes

Table 4: Observed Outcomes from LS Experiment

	1	2	3	4	Mean
1	9.00	1.0	7.00	3.00	5.00
2	2.00	6.0	3.00	14.00	6.25
3	4.00	3.0	1.00	0.00	2.00
4	2.00	4.0	2.00	4.00	3.00
Mean	4.25	3.5	3.25	5.25	4.06

- Each cell: y_{ij}
- Column: \bar{y}_r .
- Row: $\bar{y}_{\cdot c}$
- Grand mean: $\bar{y}_{..}$

ANOVA

Table 5: ANOVA Table

Source	Observed			F-Statistic
	DF	Sum Sq	Mean Sq	
water	3	44.19	14.73	1.625
speed	3	9.69	3.23	0.356
coffee	3	78.69	26.23	2.894
Residuals	6	54.38	9.06	
Total	15	186.94		

- ANOVA table from the observed data
- $F_{Tre} = 2.894$: has causal meaning
- Randomize F_{Tre} under sharp null

Sharp Null

Sharp null hypothesis

- of **no effect**
- $H_0 : y_{rc}(1) = y_{rc}(2) = y_{rc}(3) = y_{rc}(4)$
- for all r, c

Imputing

- ① Under the sharp null,
impute the missing $Y_{rc}(k)$
- ② Apply the formulation
(SSRow, SSCol, SSTre,
SSRes, SSTot) to the units

Table 6: Observed Values of the Science Table for the Coffee-ECG Experiment (row 2 and 3 omitted)

id	water	speed	coffee	Observed $y_{rc}(k)$			
				HB	W	S	De
Row 1 (Water 0 ml)							
1	1	1	1	9			
2	1	2	4		1		
3	1	3	2			7	
4	1	4	3				3
Row 4 (Water 300 ml)							
13	4	1	3				2
14	4	2	1	4			
15	4	3	4		2		
16	4	4	2			4	

Imputation of Observed Potential Outcomes

Under the sharp null,

Table 7: Imputed Outcomes under the Sharp Null

id	water	speed	coffee	Observed $y_{rc}(k)$			
				HB	W	S	De
Row 1 (Water 0 ml)							
1	1	1	1	9	9	9	9
2	1	2	4	1	1	1	1
3	1	3	2	7	7	7	7
4	1	4	3	3	3	3	3
Row 4 (Water 300 ml)							
13	4	1	3	2	2	2	2
14	4	2	1	4	4	4	4
15	4	3	4	2	2	2	2
16	4	4	2	4	4	4	4

Randomization Test

- Following the same step we learn in the class (Lee, 2021)
- Iterating 2000 times
- p-value is:

$$pvalue = 0.1$$

i.e. Not significant as in ANOVA table (p-value of 0.124)

Randomization Distribution

See the histogram.

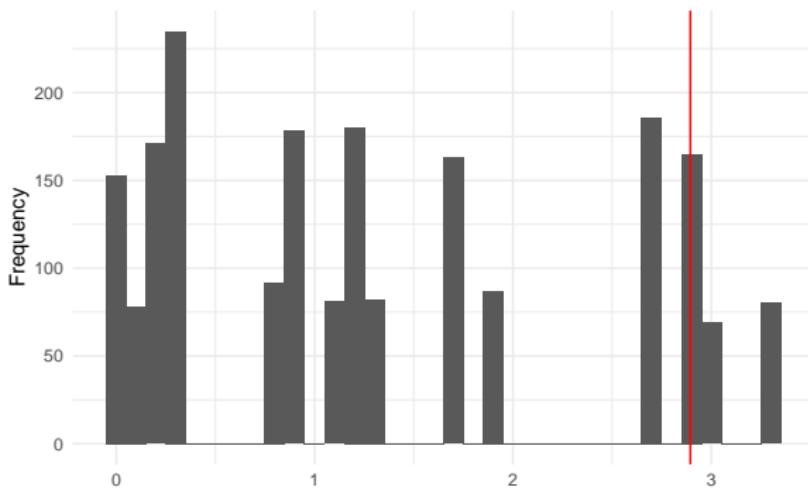


Figure 4: Randomization Distribution of F_{Tre} under the Null

Section 4

Conclusion

Conclusion

- Recall: $H_0 : y_{rc}(1) = y_{rc}(2) = y_{rc}(3) = y_{rc}(4)$
 - i.e. Caffeine's effect on average heart rate
 - We expected the effect was significant
 - However, there was *no significant evidence* (p-value of 0.1)

Discussion

Why this result?

- Caffeine **tolerance**
 - I have taken coffee everyday
 - Was coffee I have taken too small?
- **Outliers**
 - Unit 8 seems outliers
 - Table 3: value of 14

Future study

- Other samples
 - Re-define the levels of each factor
- Re-measure (for Unit 8)
 - Figure 5: Change the value of Unit 8 to 7
 - P-value becomes 0.058

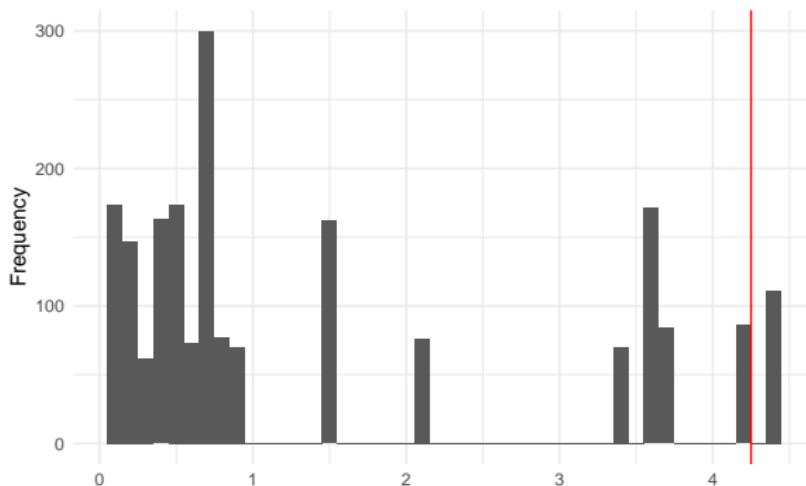


Figure 5: Changing the Outlier

Section 5

Related Contents

Codes

- My Github repository: `ecg-experiment`
 - <https://github.com/ygeunkim/ecg-experiment>
 - includes source codes for this analysis
 - and R markdown files

himynnameisabcde (2020). r/nespresso - i received the caffeine content numbers for starbucks nespresso pods!

https://www.reddit.com/r/nespresso/comments/id31r5/i_recieved_the_caffeine_content_numbers_for/.

Lee, K. (2021). Design and analysis of experiments (sta5031).
<https://icampus.skku.edu>. Accessed: 2021-03-20.

한동하 (2018). [한동하 원장의 웰빙의 역설] 냉커피는 뜨거운 커피와 어떤 차이가 있을까?

<http://www.k-health.com/news/articleView.html?idxno=37375>.